Evaluation of Proceduralized CRM at a Regional and Major Carrier

Robert W. Holt, Deborah A. Boehm-Davis, Jeffrey Hansberger
George Mason University
Fairfax, VA

Technical Report TR-GMU-01-P01

Evaluation of Proceduralized CRM at a Regional and Major Carrier

Robert W. Holt, Deborah A. Boehm-Davis, Jeffrey Hansberger
George Mason University

Traditional Crew Resource Management (CRM) has shifted focus over time from an emphasis on general principles of coordination and communication to a focus on general methods for error prevention, trapping, or mitigation (Morino, 1999). The implementation of traditional CRM typically has been at a conceptual level, which involved classroom training of principles combined with concrete examples of applications. The concepts and principles were not, however, converted into specific operational requirements represented by official documents such as the Flight Operations Manual, Flight Standards Manual, and so forth. The result has been that crew requirements were trained and assessed as general additions to, rather than as part of, Standard Operating Procedure (SOP).

This general approach to CRM had several disadvantages. First, for CRM to actually impact cockpit processes, the pilots had to understand principles correctly, apply the principles at appropriate times during the flight, and implement these principles in an effective fashion in specific situations. Since training typically has addressed understanding of the general principles and a small subset of concrete flight situations, this approach put a large burden on the pilot for appropriate application and effective implementation of CRM in day-to-day flight operations.

Second, it was difficult to integrate this general approach to CRM into pilot performance evaluation and certification. Pilots often opposed CRM evaluations based on material that was not part of SOP and for situations in which there was no specific CRM training. CRM evaluations performed at a more general level avoided some of these issues but suffered from a lack of detailed feedback for validating or changing pilot training.

Third, the general approach to CRM hindered the scientific validation of the predicted effects of CRM training. Precise predictions for specific task performance in normal and abnormal flight situations were often lacking. Lack of detailed predictions made a reliable and valid assessment of performance more difficult. Because of these disadvantages, this project developed and tested a more specific and structured form of CRM based on CRM procedures.

There were several possible advantages to using CRM procedures. If the procedures were clearly specified, they could be more easily trained and applied than general CRM principles.

Secondly, a procedural approach could raise key aspects of CRM to the level of SOP, increasing the operational significance of CRM and providing crews with a more standard form of CRM application and implementation for day-to-day operations. Further, the evaluation criteria for the performance of CRM procedures could be more explicit and less subjective. Finally, the evaluation of the specific predicted effects could more easily use standard scientific methods.

Two studies evaluated the extent to which a proceduralized version of CRM, called Advanced CRM (ACRM), would improve crew performance. The first study focused on the development and evaluation of ACRM at a regional airline. This study required four years due to the time required to develop ACRM and an extensive, multi-method evaluation in two distinct fleets. The second study was a targeted follow-up evaluation of ACRM procedures at a major airline. This study was targeted at checking the generality of the ACRM effects to the pilots, aircraft, and training scenarios used by major airlines as well as evaluating two alternative implementations of ACRM procedures.

Regional Airline Study

ACRM procedures were developed to address the CRM needs of the regional airline. Specific, targeted CRM procedures were developed for normal situations such as briefings and all abnormal flight situations covered by the airline's Quick Reference Handbook (QRH). These procedures were translated into Standard Operating Procedures (SOP) and integrated with the material in the QRH and Flight Operations Manual (FOM). For a detailed presentation of ACRM development and initial assessment see Seamster, Boehm-Davis, Holt, and Schultz (1998).

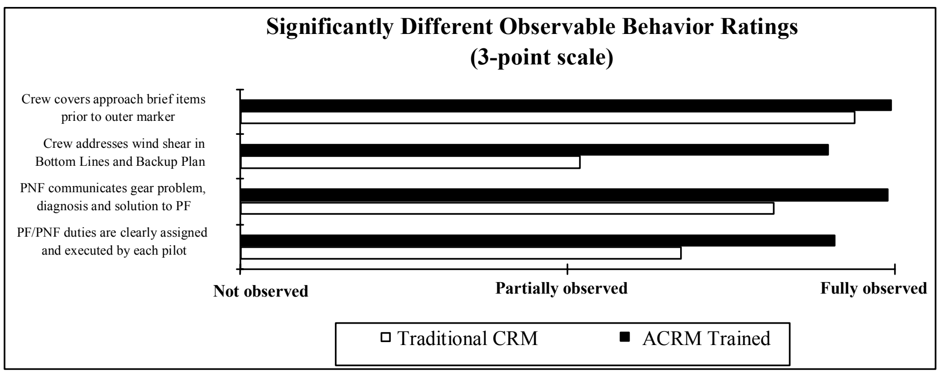
The evaluation dealt with the complexities of the operational environment by using a quasi-experimental design to compare a fleet with traditional CRM plus ACRM training (the experimental fleet) against a control fleet with traditional CRM training only. The primary evaluation measures were crew performance in each fleet on yearly recurrent Line Operational Evaluations (LOEs) and on random Line Checks. Additional evaluations were conducted using the Instructor/Evaluator (I/Es) cadre, surveys of all the airlines' pilots, and a small sample of non-jeopardy jump seat observations of line operations.

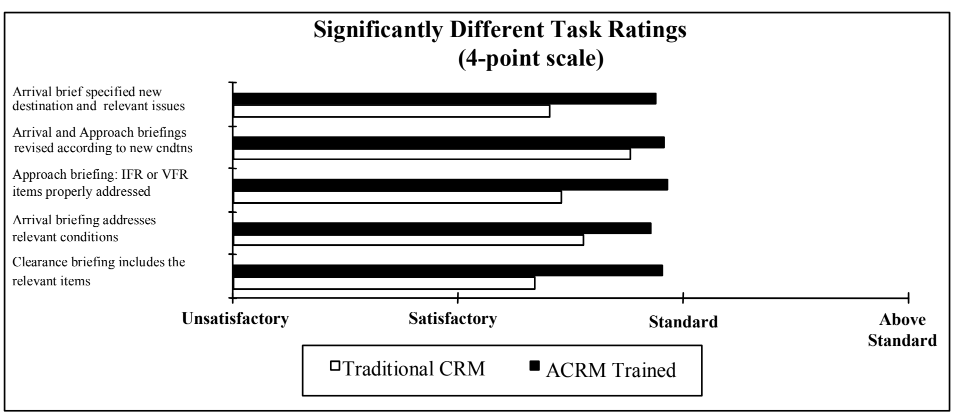
The evaluations summarized below were conducted after a year of formal implementation of ACRM as SOP in the QRH and FOM for the experimental fleet. Crews in the experimental fleet had one year of operational practice with the ACRM procedures prior to the LOEs and Line

Checks reported below. No changes were made in the control (normal CRM only) fleet during this entire period. To determine the full range of effects that ACRM had on pilot and crew performance, LOE and Line Check evaluations were augmented with jump seat observations, an instructor survey, and a pilot survey.

LOE Performance Evaluation

An LOE was developed along with ten evaluation items designed to be graded with the same standard in both the ACRM and traditional CRM-trained fleets. Four of those ten items were specific observable behaviors; the other six were more general task items. Nine of the ten items showed significantly higher scores for the ACRM fleet (see graphs below). This provided evidence that the ACRM fleet performed these observable behaviors and tasks consistently better and suggested that ACRM was having both a specific (observable behavior) as well as a more general (task items) effect on crew performance.

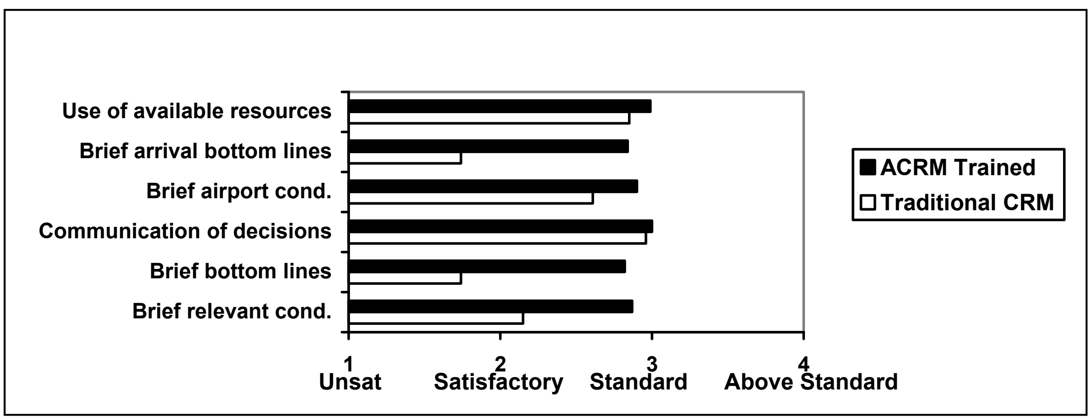




To further examine the generality of the effects of ACRM training, the four observable behaviors and the five tasks that showed significant ACRM effects were correlated with the other behaviors and tasks in the LOE for the ACRM-trained fleet. These nine items were significantly correlated with other items in the LOE to a degree greater than would be expected by chance. These results support a positive generalization of ACRM effects to other observable behaviors and tasks.

Line Check Performance Evaluation

The revised Line Check form contained twelve items that could be affected by ACRM training and SOP implementation in the ACRM-trained fleet. Since line checks occur during normal operations, most of the expected differences involved the thoroughness of the required briefings and communication in general. Since both fleets used the same Line Check form, the mean performance on these items could be statistically compared. Six of the twelve items were significantly different, with the ACRM-trained fleet performing better than the traditional CRM fleet on all six. For these items, the combination of ACRM training and implementation into fleet SOP resulted in a statistically reliable performance difference between the fleets. The ACRM fleet was also superior on the remaining six items, but these differences were not large enough to be significant.



Significantly Different Line Check Items

Additional Evaluations

To develop a complete understanding of crew performance, three additional measures were administered during the final year evaluation of ACRM. First, non-jeopardy jump seat observations were conducted by a separate group of evaluators who assessed pilots from both fleets. Jump seat observers used a form with specific items for each phase of flight. Second, an instructor survey was developed for instructors who had trained pilots from both fleets. The survey asked instructors to compare the performance of ACRM-trained with that of traditional CRM-trained pilots during transition or upgrade training. Third, a survey was developed for pilots to measure attitudes toward CRM and ACRM, knowledge and practice of ACRM procedures, and perceived effects of ACRM.

Jump seat observations. Jump seat observations used the same performance criteria for rating crews from each of the two fleets during normal flight operations. A sample of 48 crews was rated on performance items during each of the major phases of flight (take-off, cruise, and approach/descent) and on their overall flight performance. Statistical analyses revealed that thirteen of the twenty items were significantly different, all in favor of superior flight performance in the ACRM fleet. Included in these thirteen items were the overall effectiveness items from the take-off, cruise, and approach/descent phases of flight and the overall effectiveness item referring to all phases of flight. Although the sample size for this part of the evaluation was relatively small, the fleet differences on these thirteen items were generally large.

Instructor/Evaluator survey. All the Instructor/Evaluator's (I/Es) for the regional airline were asked to compare pilots with ACRM training and those with traditional CRM training on the basis of the frequency and quality of specific behaviors. I/Es were asked to judge the relative performance during training of pilots with or without ACRM training and experience. Preliminary analyses of the judgments by the 19 I/Es who had trained pilots in both fleets revealed three distinct factors of perceived crew performance: workload management, planning, and communication. Analysis of the workload management factor indicated that ACRM-trained pilots managed workload more frequently and with better quality than traditional CRM-trained pilots. Analysis of the planning factor indicated that ACRM-trained pilots planned more frequently and with better quality. Analysis of the communication factor indicated that ACRM-trained pilots communicated more frequently and with better quality. In summary, across all three of these basic crew performance factors, instructors' evaluations of ACRM-trained pilots versus pilots with traditional CRM only were significantly in favor of ACRM-trained pilots.

Pilot survey. The pilot survey included knowledge of ACRM, practice of ACRM procedures, and attitudes toward CRM and ACRM. For pilots trained with traditional CRM only, the pilot survey only measured general attitudes toward CRM and ACRM. The traditional CRM-only pilots were not asked about detailed ACRM knowledge, practice of ACRM procedures, or the perceived effects of ACRM as those items could not be sensibly answered without the ACRM training and experience.

The pilot survey results also strongly support the ACRM procedures. ACRM-trained pilots had very positive attitudes toward CRM in general and ACRM in particular. ACRM-trained pilots showed significant knowledge of ACRM, and reported frequently performing ACRM procedures. Furthermore, they perceived significant benefits to performing the ACRM procedures, and overwhelmingly endorsed the continuation and extension of the ACRM program to other fleets in the airline. The frequent performance of ACRM procedures was expected, and confirmed the effectiveness of implementing these procedures as SOP for the fleet. The positive attitudes and perceived benefits of ACRM indicated significantly positive pilot responses to the ACRM procedures as trained and implemented in SOP.

Regional airline summary. The possible effects of ACRM were examined with different evaluation methods, different samples of evaluators, and different samples of evaluated behaviors. Differences in performance and other types of supporting evidence confirm ACRM effects. The convergence of these different methods on showing positive effects of ACRM training and SOP implementation was compelling evidence that proceduralization of CRM did have positive effects on line crews at a regional airline. The generalizability of the effects of ACRM were evaluated by a follow-on study at a major airline.

Major Airline Study

The evaluation study at the major airline was a field experiment designed with two distinct goals. The first goal was to examine whether the ACRM results would be generalized to major airline pilots, equipment, and evaluation scenarios. This required a comparison of a set of crews trained to use ACRM procedures integrated as SOP in their fleet FOM (integrated ACRM group) with a set of crews using the ordinary airline training and procedures (control group). The second goal was to examine whether the ACRM procedures could be effectively condensed into a separate, stand-alone checklist rather than being integrated with all the details for each procedure in the FOM. To examine this, a stand-alone version of the ACRM procedures was constructed and used for a third set of crews (stand-alone ACRM group) in this study.

Predictions. Congruent with the previous results for the regional airline, we predicted that the integrated ACRM group would perform better than the normal group. The addition of the stand-alone group was to see if a generic form of ACRM procedures could also have a beneficial effect on crew performance. Although no previous study has examined this type of generic crew checklist, we hoped that that the stand-alone ACRM group would have performance somewhat better than the normal group.

Design. One problem with the use of a quasi-experimental design in the regional airline study was the lack of randomized assignment of pilots and crews to training conditions. In that study, pilots were assigned to fleets using normal management methods and pilot seniority at the airline. Since the assignment of pilots to fleets (and the associated training) was not random, we could not ensure that all pilot variables (such as background experience, age, etc.) were equal in the experimental and control fleets.

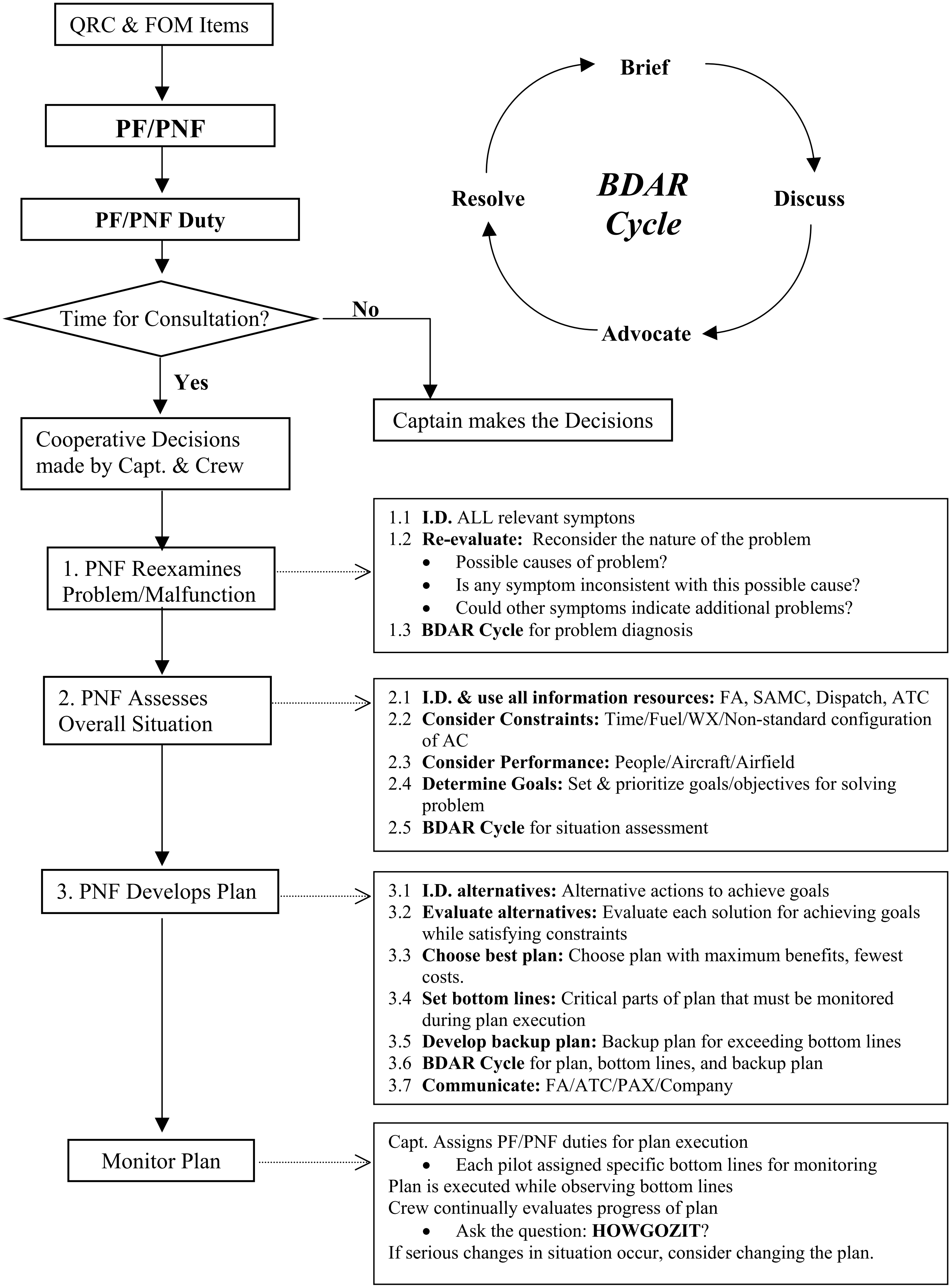
Therefore the follow-on study was designed as a field experiment with the random assignment of volunteer crews to three different training conditions: control group, integrated ACRM group, and stand-alone ACRM group. The training and evaluation was performed during the normal yearly recurrent training for these pilots. This training and evaluation event lasted three days and included both Line Operational Flight Training (LOFT) and Line Operational Evaluation at the end of the event (LOE). All evaluations were based on crew-level performance of crews comprised of a Captain and a First Officer who were assigned together for training but had typically not flown together previously. The three-day window was sufficient to give all pilots a basic classroom training of ACRM principles and procedures, but did not include the extensive ACRM training and one-year operational experience with ACRM of the pilots at the regional airline. The evaluation for this study was a non-jeopardy evaluation in that all participating pilots had the right to re-take the LOE under standard company conditions if they failed the LOE during the experiment. In fact, none of the volunteer crews failed the LOE during the experiment, so this option was not needed.

<u>Materials</u>

Once they had volunteered for the study, all pilots were given the same basic training on ACRM principles. This training consisted of a six-page document that was read and discussed by the instructor/evaluator with both members of the crew during the preparation for the training event. The I/Es were given similar preliminary training in the ACRM principles and procedures together with training in judging ACRM performance and using the airline's traditional worksheets and a modified evaluation form. The only difference in the assigned conditions for the crews was in the basic materials used by the crew during the training and evaluation, which varied for each group. This fleet used three different forms for the LOE so that pilots were less able to communicate the contents of the LOE to other pilots or to anticipate the requirements of the LOE for crew performance. Each form of the LOE used a different critical event: failure of a critical indicator light, partial hydraulic failure, and in-flight engine failure and shutdown.

Control group. The control group had completely normal airline CRM procedures and the standard FOM and Quick Reference Card (QRC). Thus, the ACRM procedures were discussed but were not implemented as SOP for this group during the training event. Performance in this group was intended to represent as closely as possible the normal baseline for the participating fleet and airline.

Stand-Alone ACRM group. The stand-alone ACRM group had the standard airline FOM and QRC plus a separate 2-page ACRM checklist. This checklist summarized a generic form of the ACRM procedures that were generally appropriate for most abnormal or emergency flight situations. Initially, the QRC and FOM reference items were completed first, followed by the generic ACRM procedures. The generic ACRM procedures were to assign pilot flying and pilot not flying duties, to determine time available for consultative decision-making, to completely diagnose the problem, to assess the big picture using all information sources, to develop a plan with bottom lines and a backup plan, and finally to execute and monitor the plan. Figure 1 illustrates the flow and structure of the ACRM procedures used by the major carrier. These procedures integrated the airline's philosophy and policy with the specific ACRM procedures such as the Brief-Discuss-Advocate-Resolve cycle (BDAR Cycle).


QRC & FOM Items
PF/PNF
PF/PNF Duty
Time for Consultation?
No
Yes
Captain makes the Decisions
Cooperative Decisions made by Capt. & Crew
Brief
Discuss
Advocate
Resolve
BDAR Cycle
1. PNF Reexamines Problem/Malfunction
1.1 I.D. ALL relevant symptons
1.2 Re-evaluate: Reconsider the nature of the problem
• Possible causes of problem?
• Is any symptom inconsistent with this possible cause?
• Could other symptoms indicate additional problems?
1.3 BDAR Cycle for problem diagnosis
2. PNF Assesses Overall Situation
2.1 I.D. & use all information resources: FA, SAMC, Dispatch, ATC
2.2 Consider Constraints: Time/Fuel/WX/Non-standard configuration of AC
2.3 Consider Performance: People/Aircraft/Airfield
2.4 Determine Goals: Set & prioritize goals/objectives for solving problem
2.5 BDAR Cycle for situation assessment
3. PNF Develops Plan
3.1 I.D. alternatives: Alternative actions to achieve goals
3.2 Evaluate alternatives: Evaluate each solution for achieving goals while satisfying constraints
3.3 Choose best plan: Choose plan with maximum benefits, fewest costs.
3.4 Set bottom lines: Critical parts of plan that must be monitored during plan execution
3.5 Develop backup plan: Backup plan for exceeding bottom lines
3.6 BDAR Cycle for plan, bottom lines, and backup plan
3.7 Communicate: FA/ATC/PAX/Company
Monitor Plan
Capt. Assigns PF/PNF duties for plan execution
• Each pilot assigned specific bottom lines for monitoring
Plan is executed while observing bottom lines
Crew continually evaluates progress of plan
• Ask the question: HOWGOZIT?
If serious changes in situation occur, consider changing the plan.

During the first month of data collection, crews objected to the placement of the ACRM checklist after the completion of the QRC and FOM procedures. Crews felt the ACRM checklist was redundant and essentially unnecessary after completion of QRC and FOM procedures to handle the abnormal or emergency situation. Therefore, this condition was modified so that the generic ACRM procedures were interleaved with the normal airline procedures in the following order:

1. Any appropriate memory items were performed immediately.
2. QRC items were performed.
3. The following ACRM procedures were performed:

3.1 Pilot Flying and Pilot Not Flying duties were assigned

3.2 Check problem diagnosis

3.3 Update the Situational Assessment

4. FOM procedure for the abnormal or emergency was performed
5. The remaining ACRM procedures were performed:

5.1 Brief, Advocate, and Resolve the revised Situational Assessment

5.2 Develop plan including bottom lines and backup plans]

5.3 Brief, Advocate, and Resolve the plan

5.4 Execute and monitor the plan

This interleaved form of the generic ACRM checklist and normal airline procedures was used for the stand-alone ACRM condition for the remainder of the study.

Integrated ACRM group. The integrated ACRM group had ACRM procedures integrated into the airlines FOM procedures for each abnormal or emergency used in the evaluation in a similar fashion to the revised QRH at the regional airline. Since each version of the LOE had a different critical event that required the crew to use a different part of the FOM, the ACRM procedures had to be integrated with three sections of the FOM. Subject-matter experts (SMEs) from the airline interacted with the research team to design the integrated procedures for the FOM sections for failure of a critical indicator light, partial hydraulic failure, and in-flight engine failure and shutdown.

In each case, the general ACRM procedures were specified to be applicable to the specific section of the FOM. The SMEs and the research team redesigned the FOM sections to preserve the flow of actions of the FOM while accommodating the ACRM procedures in the most natural and operationally useful manner. Detailed FOM content was also reorganized where appropriate using the ACRM procedures as a framework for clustering or grouping related material. Finally, each ACRM procedures was specified by including specific FOM content that was judged to be appropriate for that procedure. For example, after an engine failure and shutdown, the situational assessment procedure contained the FOM reference to limitations for single-engine operations that would plausibly be expected to affect the situational assessment (see Appendix A).

Procedure

After development of the materials and obtaining necessary approvals from the FAA, the fleet officials, and the pilots' union, the I/Es were trained. This training consisted of a presentation of the ACRM principles by an airline SME and review and discussion of the training materials designed to be used for pilots in the study. The I/Es also had an additional section on the evaluation of ACRM procedures since they were required to evaluate crew performance using the normal airline worksheet and the special evaluation form developed for this study.

An on-site research liaison pilot solicited crews for volunteering for this study using a consent form designed by the research team. Since training and evaluation is conducted on a 24 hour basis at this training center, solicitation was limited because the liaison pilot could not solicit participation by crews at all times of the day and night. All crews volunteering for the study were randomly assigned to the three experimental conditions using stratified random assignment. Crews that did not volunteer were, of course, assigned to the normal condition for taking the LOE as that was the airline's standard LOE evaluation procedure. Since all non-volunteering crews and 1/3 of the volunteer crews received the standard evaluation procedure, the number of crews in the normal condition is much larger (N = 170) than the number of crews in the integrated ACRM or separate ACRM conditions (N = 24 and 21, respectively).

The critical evaluation used to test the effects of ACRM was the LOE at the end of the 3-day training event. Different versions of the LOE had different critical events, but all LOE versions had this critical event as the seventh evaluated flight segment. This flight segment involved the aircraft making an initial approach to landing which had to be aborted by the occurrence of one of the critical events. However, the flight segments prior to this critical flight segment were, identical for all versions of the LOE and did not require the use of the FOM or any ACRM procedures. These initial flight segments can therefore be used to see if the experimental groups were equivalent in performance up to the point of the critical event.

Data Analysis Approach. Given the unequal sample sizes, the data were analyzed using an unweighted means approach. That is, the basis of the analysis for this report was the mean score for each item for each month rather than the case-by-case information. Therefore, for all the following analyses, a single score represents the average of an item for each month across all pilots in a particular condition. The unweighted means approach essentially eliminates the effect of having many more crews in the normal group compared to the integrated ACRM or stand-alone ACRM groups, but this approach also reduces the degrees of freedom for the error term and thereby reduces statistical power. The analyses reported below focused on overall CRM and technical performance ratings for each event set made on the standard airline LOE worksheet by the I/Es. I/Es rated each crew on each event set on a four point scale with the following anchors: 1 = Repeat (fail), 2 = Debrief (unsatisfactory), 3 = Standard (airline performance standards), 4 = Excellent (above airline standards). The CRM and technical ratings were made at the crew level for each event set and therefore represent the joint performance of the Pilot In Command (PIC) and the Second In Command (SIC).

Baseline performance. Assuming our random assignment procedure was effective, the baseline crew performance on the six flight segments before the critical segment was expected to be similar for all three groups. As expected, the three experimental groups were not significantly different for either CRM or technical performance for these segments ($F\,(2, 15) = 0.75$, 1.87, respectively, $p > .10$ for both comparisons). Within the limits of power for this analysis, the groups were initially equivalent in performance.

Critical Event set performance. The integrated ACRM group had one month with no assigned volunteers, so the total data for this analysis were 12 months for the normal group, 12 months for the stand-alone ACRM group, and 11 months for the integrated ACRM group. The groups were, as expected, significantly different in CRM and technical performance across the 12 months of the study. The overall test of group differences was significant both for crew CRM and technical performance ($F\,(2, 32) = 10.81$ and 5.84, $p < .01$ for both comparisons).

The mean performance for CRM and technical performance for each group is given in the table below. This pattern of means suggests that the ACRM group was better than either the normal or the separate ACRM groups, but the ACRM group is worse than the normal group. The significant overall differences were further explored with post-hoc tests.

Groups	*Count (months)*	*Average CRM*	*Average Technical*
Integrated ACRM	11	2.92	2.91
Separate ACRM	12	2.54	2.58
Normal	12	2.80	2.80

Post-hoc paired *t*-tests were conducted to determine if the pattern of means were reliably different for each pair of groups across the 12 months. To enable a comparison using all 12 months, the overall average for CRM and technical performance for the integrated ACRM group was substituted for the one month of missing data.

The post-hoc tests indicated that the separate ACRM group was significantly worse in CRM scores compared to either the integrated ACRM group (t (11) = -4.04, $p < .01$) or the normal (t (11) = -3.16, $p < .01$) group. These tests also indicated a tendency for the integrated ACRM group to be superior to the normal group (t = 2.06, p = .06 two-tailed or p = .03 one-tailed). Since the *a priori* hypothesis was for the integrated ACRM group to be superior, the one-tailed test is justified. Overall, the pattern is that the integrated ACRM group is superior to the normal group, which in turn is superior to the stand-alone ACRM group. These results confirm the main expectation of this study that the integrated ACRM procedures would facilitate crew performance. However, these results disconfirm the hope that a generic, stand-alone version of the ACRM procedures could have a positive effect. In fact, the stand-alone ACRM group is worse than either the normal or the integrated ACRM group.

The pattern of mean differences for technical performance is similar, although weaker, to the pattern for CRM performance. The post-hoc tests indicated that the separate ACRM group was significantly worse in technical scores compared to either the integrated ACRM group (t (11) = -3.45, $p < .01$) or the normal (t (11) = -2.89, p = .01) group. These tests also indicated a weak tendency for the integrated ACRM group to be superior to the normal group (t (11) = 1.50, p =

.16 two-tailed or $p = .08$ one-tailed). Although this result may suggest a superiority of the integrated ACRM group to the normal group, the results are too weak to statistically confirm the difference. Overall, the pattern is that the integrated ACRM group and normal group are both superior to the stand-alone ACRM group. These results once again disconfirm the hope that a generic, stand-alone version of the ACRM procedures could have a positive effect, but they leave open the question of whether integrated ACRM procedures combined with limited training can also facilitate technical performance. Hopefully this issue can be clarified by further analysis of the case-by-case data when it becomes available.

Discussion

The first study of this report focused on a regional airline in which the ACRM procedures were developed, trained, implemented as SOP, and evaluated over time in a quasi-experimental design. The results of five different evaluation methods at the regional airline supported the effectiveness of ACRM procedures implemented as SOP. This congruence of results supports the conclusion that carefully proceduralized CRM can effectively increase crew performance.

The second study of this report focused on a major domestic airline for which the ACRM procedures were adapted and evaluated in a field experiment using volunteer crews undergoing their yearly recurrent training and evaluation under AQP. This study controlled for systematic group differences but had much more limited training than at the regional airline and a very temporary use of the ACRM procedures for the training event only compared to the incorporation of ACRM as permanent fleet SOP at the regional airline. Nevertheless, this study also found confirmatory effects of integrated ACRM procedures for facilitating crew CRM performance in critical flight situations. However, this study disconfirmed the utility of a stand-alone generic form of ACRM procedures using a checklist format. Using a generic form of ACRM procedures as a separate checklist decreased both crew CRM and technical performance compared to a normal set of crews.

From these findings, we conclude that proceduralization of CRM must be reasonably integrated into fleet SOP and normal procedures to be effective. That is, the ACRM procedures must be incorporated as seamlessly as possible into the normal flows, checklists, or action sequences of the FOM, FSM, QRH, QRC, and all other official procedures. An effective integration will potentially yield increases in CRM and technical performance. Conversely, based on the current results, attempts to separate ACRM principles from the content and context of action do not appear to be successful.

We do not know if this lack of effect was due to a poor implementation in the second study or whether the approach of separating CRM from normal flows and procedures is inherently flawed. Considering the issues raised in the introduction, the separation of CRM concepts from the site of necessary cognitive activation and behavioral implementation may simply not work due to the extra cognitive demands placed on pilots, who are required to correctly identify the time, context, and method of application of the general principles. Research in situated cognition would suggest, for example, that the trained cognition should be associated as closely with the context of application as possible. Considerations such as this would support the development and use of integrated ACRM procedures rather than stand-alone versions.

References

Maurino, D.E. (1999). Crew resource management: A time for reflection. In D.J. Garland, J.A. Wise, V.D. Hopkin (Ed.) *Handbook of Aviation Human Factors.* Lawrence Erlbaum, New Jersey.

Seamster, T.L., Boehm-Davis, D.A., Holt, R.W., & Schultz, K. (1998). *Developing Advanced Crew Resource Management (ACRM) Training: A Training Manual.* Washington, DC: Federal Aviation Administration, AAR-100.

Acknowledgements

This research was supported by the Office of the Chief Scientific and Technical Advisor for Human Factors (AAR-100) of the Federal Aviation Administration through FAA grant 94-G-034 to George Mason University. The opinions and conclusions expressed in this document represent the authors' viewpoints and do not represent official opinions of the FAA, the U.S. government, GMU, or any of the airlines participating in this research.

The authors thank the following individuals for their support during the execution of this project: Jeffrey Beaubien, Brad Blythe, Dr. Eleana Edens, Dr. Donna Williams Greenwood, Dr. William Hamman, Dr. Philip Ikomi, Kara Incalcaterra, Dr. Thomas Longridge, Capt. Kim Schultz, and Dr. Thomas Seamster.

"A" HYDRAULIC SYSTEM QUANTITY OR PRESSURE LOSS

Assign PF/PNF duties

PNF Re-examines problem/malfunction

Check both "A" hydraulic low pressure lights and "A" hydraulic quantity.

Check other aircraft systems for problems/malfunctions:

- Resolve any inconsistencies for problem definition.

Discuss and confirm Problem/malfunction with PF.

<u>If one "A" hydraulic pump low pressure light is on:</u>

Affected "A" hydraulic pump……………………………………………OFF

"A" hydraulic quantity…………………………………………………Check

If quantity is ¼ (25% EIS) or greater:

Checklist is complete.

If quantity is less than ¼ (25% EIS):

Continue checklist.

<u>If both "A" hydraulic pump low pressure lights are on or "A" hydraulic quantity is less than ¼ (25% EIS):</u>

Both "A" hydraulic pumps………………………………………………OFF

"A" Flight control switch………………………………………………STBY RUD

"A" Spoiler switch……………………………………………………..OFF

If use of autopilot is desired:

Autopilot “B”……………………………………………………ENGAGE

If airplane is equipped with alternate nose wheel steering:
Nose wheel steering switch………………………………………ALT

PNF Assesses overall situation:

General: Fuel/time available, airports available, WX conditions, performance limitations of AC.

Inoperative units are:
Inboard flight spoilers.
Ground spoilers.
System “A” nose wheel steering (Is alternate steering usable?).
Autopilot “A” (Is Autopilot “B” engaged?).

Backup systems:
Gear extension: manual (gear cannot be retracted).
No. 1 thrust reverser: standby hydraulics
(longer operation time than No. 2 thrust reverser).

Brief, Advocate, and Resolve the Situation Assessment with PF.

PNF Develops Plan (using SAMC, Dispatch, ATC or other sources) considering:

Best airport selection:

Lack of nose wheel steering requires closing down a runway after landing and availability of a tow vehicle.

Minimum desirable runway length considering the lack of spoilers and longer time for No. 2 thrust reverser to deploy.

Best time for manual gear extension:

Extension should be sufficiently early to allow time for manual extension.

Extension should not be too early because of increased drag characteristics.

Set Bottom Lines for bank angle, approach speed and touchdown point necessary for making the landing.

Set Back-Up Plan for go-around considering aircraft handling and performance limitations considering gear cannot be retracted after extension.

Brief, Advocate, and Resolve the Plan with PF.

Monitor Plan

Captain assigns PF/PNF duties for Plan execution:

- Each pilot assigned specific Bottom Lines for monitoring.

Evaluate progress of Plan. (HOWGOZIT?)

When manual gear extension is desired, accomplish the following:

MANUAL GEAR EXTENSION

Airspeed……………………………………………………………………Max 270 KIAS/.82Mach

Landing gear level…………………………………………………………OFF

Manual gear extension T-Handles…………………………………………PULL HARD

Note:

Wait 15 seconds before moving the landing gear level down after the last manual gear extension T-handle is pulled.

Green gear lights…………………………………………………………..Check 3 ON
Landing gear lever…………………………………………………………DOWN

Caution

Use discretion when planning thrust reverser operation without nose wheel steering. To maintain directional control use differential braking and aerodynamic steering. If using reverse thrust, do not come out of reverse thrust until airplane stops.

Before Final Descent Checklist, accomplish the following after gear and flaps are down:

"A" electrical hydraulic pump……………………………………………..ON

If normal "A" pressure IS indicated (after a few seconds):
Nose wheel steering may or may *not* be available.

If normal "A" pressure is Not indicated (after a few seconds):
"A" electric hydraulic pump………………………………………OFF

PNF monitors bank angle, approach speed and touchdown point Bottom Lines and makes call-outs.

AUTO FAIL LIGHT - ON

Assign PF/PNF Duties.

PNF Re-examines problem/malfunction

Check autopressure controller switch and pack switches.

Check other aircraft systems for problems/malfunctions:

- Resolve any inconsistencies for problem definition.

Discuss and confirm problem/malfunction with PF.

Note: Increasing thrust may ensure adequate air supply to control cabin altitude.

PRESSURIZATION MODE SELECTOR……..…………STBY

<u>If pressurization normal</u>:

PRESSURIZATION MODE SELECTOR…RETURN TO AUTO

If pressurization remains normal and AUTO FAIL light is off,
Checklist is complete.

If AUTO FAIL light is on or pressurization is not normal:

PRESSURIZATION MODE SELECTOR……..…………………STBY

Climb and Cruise:
CAB ALT………………….SET USING CAB/FLT PLACARD

Prior to Descent;
CAB ALT………………SET 200 FEET BELOW FIELD ELEV.

Checklist complete.

If STBY cannot maintain cabin pressurization:

PRESSURIZATION MODE SELECTOR……MAN AC OR DC

FLT/GRD SWITCH………………………………………GRD

OUTFLOW VALVE SWITCH…………….……AS REQUIRED

If pressurization CAN be brought under control:

FLT/GRD SWITCH………………………………………..FLT

Continue to adjust cabin altitude and rate as required.

Continue Checklist.

Prior to Landing (below 10,000 ft MSL):

OUTFLOW VALVE……………………POSITION FULL OPEN

If pressurization CANNOT be brought under control and cabin altitude is in imminent danger of exceeding 10,000 ft.:

Use QRC Cabin Altitude Warning/Rapid Decompression.

If pressurization CANNOT be brought under control and cabin altitude is NOT in imminent danger of exceeding 10,000 ft.:

PNF Assesses overall situation:

General: Fuel/time available, airports available, WX conditions, performance limitations of AC,
initiating descent.

PNF Develops Plan (using Maintenance, Dispatch, ATC or other sources) considering:

Consider notifying ATC, turning off course for descent, check MSA and MEA.

Notify Flight Attendant.

Set Bottom Lines for initiating descent immediately. If cabin altitude is in imminent danger of
exceeding 10,000 ft.:

Use QRC Cabin Altitude Warning/Rapid Decompression.

Set Bottom Line for minimum safe altitude for AC using MSA and MEA.

Set Bottom Lines for fuel/airport, fuel burn to destination, quality of cabin air.

Brief, Advocate, and Resolve the Plan with PF.

Brief Flight Attendant.

Monitor Plan

Captain assigns PF/PNF duties for Plan execution:

- Each pilot assigned specific Bottom Lines for monitoring.

Evaluate progress of Plan. (HOWGOZIT?)

INFLIGHT ENGINE SHUTDOWN

Assign PF/PNF duties

PNF Re-examines problem/malfunction

Consider:

If engine has flamed out and you are attempting a restart:

- Go directly to Engine Start Irregular procedure.

Re-check which engine has the problem/malfunction.

Check other aircraft systems for problems/malfunctions:

- Resolve any inconsistencies for problem definition.

Discuss and confirm problem/malfunction with PF.

Autothrottle…………………………………………………OFF

Throttle……………………………………………………..Confirm, idle

Start Lever…………………………………………………Confirm, cutoff

QRC Driftdown procedure…………………………………Consider

APU (if available)…………………………………………..Start

APU generator………………………………………………ON, as required

Pneumatics and air conditioning……………………………Adjust

If wing anti-ice is required:

Pack (affected side)…………………………………..OFF

Isolation valve………………………………………..AUTO

APU bleed switch……………………………………OFF

Engine bleed switch (operating engine)………………ON

Wing anti-ice…………………………………………ON

Fuel……………………………………………………………..Balance

Use CTR fuel first: monitor balance.

GPWS flap inhibit switch………………………………………Inhibit

Transponder……………………………………………………TA only

(Prevents climb commands exceeding single engine performance capabilities.)

PNF Assesses overall situation:

General: Fuel/time available, airports available, WX conditions, performance limitations of AC:

- Single-engine performance limitations.

Brief, Advocate, and Resolve the Situation Assessment with PF.

PNF Develops Plan (using SAMC, Dispatch, ATC or other sources) considering:

Best airport selection:

Closest airport in distance and time.

Single engine performance limitations and weather at suitable airports.

Services available at airport.

Use of autopilot for approach.

Discuss technique for centering of rudder trim on landing.

Set Bottom Lines using Single Engine approach and landing profile (FOM reference page ___).

Set Back-Up Plan using single engine go-around procedures and performance limits.

Brief, Advocate, and Resolve the Plan with PF.

Monitor Plan

Captain assigns PF/PNF duties for Plan execution.

- Each pilot assigned specific Bottom Lines for monitoring

Evaluate progress of Plan. (HOWGOZIT?)